Novel Physical Behavior of Nanostructured Materials Derived From Interface Atoms

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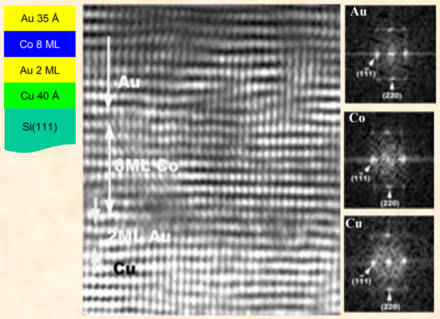
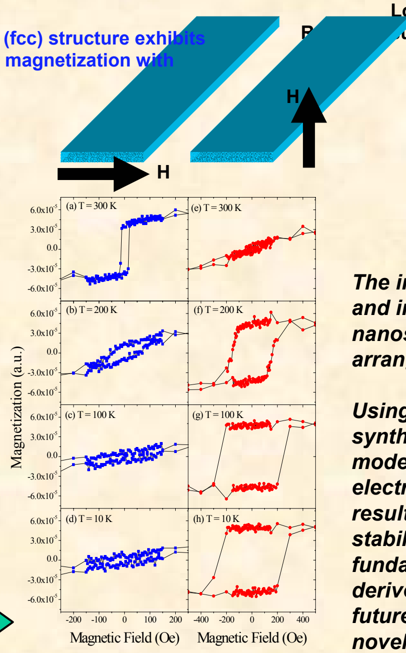
Cobalt stabilized in the unusual face-centered cubic (fcc) structure exhibits in-plane magnetization that switches to out-of-plane magnetization with decreasing temperature



High-resolution transmission electron microscopy (HRTEM) indicates an unusual fcc structure for Co grown on 2 ML Au under layer that is lattice matched to fcc Cu.

Magnetization measurements parallel (perpendicular) to the sample plane reveal in-plane magnetization for fcc Co at room temperature, that rotates to out-of-plane magnetization as the temperature is decreased.

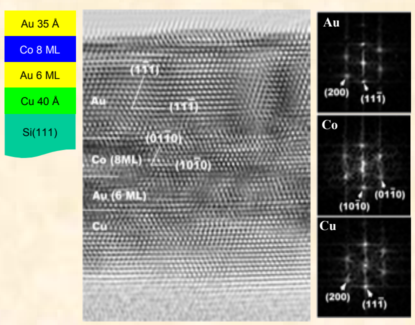


The increased fraction of atoms at surfaces and interfaces, as compared to bulk, in nanoscale materials result in new atomic arrangements with unusual physical behavior.

Using an approach that integrates nanoscale synthesis and characterization with atomistic modeling, our team is exploring the novel electronic, magnetic and optical properties resulting from the new atomic structures stabilized at strained interfaces. This fundamental study of material properties derived from interface atoms would lead to future multifunction nanoscale devices with novel and enhanced functionality.

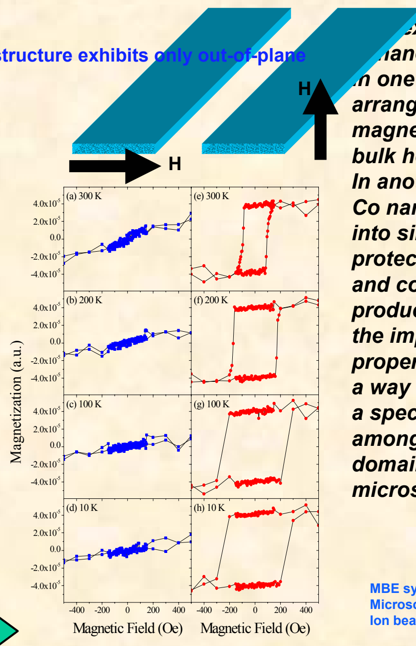
Examples of unusual magnetic behavior in nanoscale Co are shown here. In one case, stabilization of a new atomic arrangement (fcc Co) resulted in unusual magnetization response as compared to the bulk hcp structure of Co. In another case, self-assembly synthesis of Co nanodots was achieved by ion implantation into silica. Advantages of this technique are the protection of nanodots from the environment and compatibility with microelectronic production lines. A direct correlation between the implantation dose and the size and magnetic properties of the nanodots was found, providing a way to tailor-design the nanodots according to a specific application. After annealing, interaction among the nanodots generated large magnetic domains as observed by magnetic force microscopy.

Cobalt in the bulk hexagonal closed packed (hcp) structure exhibits only out-of-plane magnetization from 10 K to 300 K

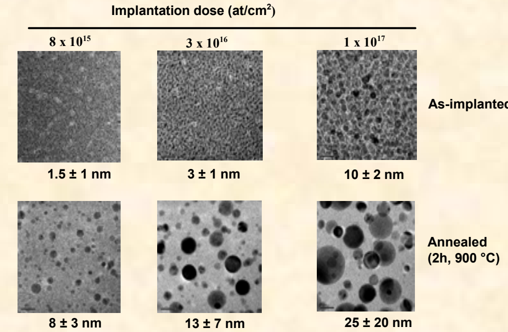


HRTEM indicates that Co grown on 6 ML Au underlayer exhibits the hcp structure typical of bulk Co.

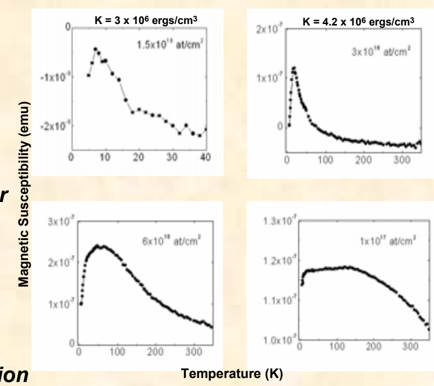
Magnetization measurements parallel (perpendicular) to the sample plane reveal out-of-plane magnetization for hcp Co at room temperature. Unlike the fcc Co case shown above, no change in the magnetization direction is observed as temperature is decreased to 10 K.



Ion Implantation is used to Synthesize Self-assembled Nanodots of Co



Cobalt dots show a characteristic superparamagnetic behavior at nanometer dimensions

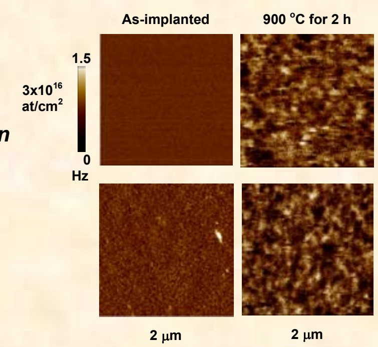


$25kT_{peak}=KV$

where
k = Boltzmann constant
T_{peak} = magnetic susceptibility peak temperature
K = magnetic anisotropy constant
V = volume of the nano-dot

Nano-dots of Co have a higher magnetic anisotropy constant as compared to bulk Co ($K = 2.5 \times 10^6$ ergs/cm^3). At higher ion-dose, a broad peak is observed due to interaction between larger size dots.

Magnetic Force Microscopy



MBE synthesis in collaboration with C.M. Falco (University of Arizona).
Microscopy performed at LANL Electron Microscopy facility.
Ion beam synthesis performed at LANL - IBML facility.